science. To me it contains a lesson, in point, of great importance. The opportunity offered them was beset with difficulties. No bribes such as scholars or students expect to-day were offered them; they knew no examinations, and their available apparatus and laboratory equipment were of the smallest and crudest description; but they were eager students with whom the master was in sympathy, and it is common knowledge that they completed the foundations of our science. Now I ask, considering the thousands of students whom we teach and examine to-day, are we doing as well in the interest of the country as our predecessors a century ago? Who can confidently answer in the affirmative? No; whatever else is done, the country needs the provision of men whose untrammelled energy should be devoted to original chemical research. Even as intellectual discipline the value of research is of the highest importance. In his address to the British Association at Winnipeg, Prof. Sir J. J. Thomson bears testimony to this. He says: "I have had considerable experience with students beginning research in experimental physics, and I have always been struck by the quite remarkable improvement in judgment, independence of thought, and maturity produced by a year's research. Research develops qualities that are opt to atrophy when the student is preparing for examinations, and, quite apart from the addition of new knowledge to our store, is of the greatest importance as a means of education."

And the object and ideal are wrong also in our system of technical training. We aim too much at giving elementary instruction to artisans, which, though important in itself, can never take the place of the higher education of leaders or managers of industrial works. This is different in Germany, where, although the training of artisans is by no means neglected, the chief energy is directed to the training and teaching of the smaller class of managers. There is, too, in Germany a far more intimate relation between academic and industrial work, and the leaders in each often interchange posts. In one respect we have an advantage over Germany; it is important that this should be understood. The higher technical instruction across the Rhine has not been undertaken by the universities, but is carried out in separate institutions. With us the universities have gradually undertaken, in addition to the older technical subjects, theology, medicine, and law, the various branches of engineering and agriculture, and even commerce. This, it is to be hoped, will be extended so that the highly trained technologist may have the advantage of the undoubted humanising influence of the university.

Conclusion.

I have not attempted in this address any complete survey of chemistry, either its growth in the past or its present condition, but I have endeavoured to give some account of the sort of thing chemistry is—of its method—and to maintain three theses: (1) That the logical method by which chemistry advances is not a simple one, and requires as one essential element the use of a highly developed imagination. To render this more efficient I have advocated special training. (2) Without violating, I hope, the canons of the proper use of hypothesis, I have proposed, in order to account for certain isomeric and other phenomena, the conception of solid molecular aggregates, although I am not able at present to indicate precise methods for its further investigation. These molecular aggregates are supposed to be formed by the combination of gaseous molecules just as the latter are formed by the combination of atoms. (3) As a matter of vital interest to the continued well-being of this country I have insisted strongly that our educational resources devoted to chemistry should be directed, in the first place and chiefly, to the highest possible training of promising students in the prosecution of research, and that the giving to the many of elementary instruction should be at least a secondary consideration.

Now I do not wish to dictate how this last proposition could be best carried into effect. I think we should distinguish three classes of chemists, or technical chemists, whose domains would more or less overlap. Occasionally there will be a man, like the late Sir William Perkin, who would combine all three. The three classes are: first, the pure chemist, devoted to scientific discovery only; second, the technical chemist, who prepares the discoveries of the pure chemist for the technologist, and has to determine such questions as economical production and, for example, the conversion of colours into dyes; third, the technologist or works manager. These three classes should be in close relation to one another. By such a scheme we should probably overcome by education one of our most serious present difficulties—the ignorance of owners of works of the value of science.

It is a matter deserving most earnest consideration whether, under the propitious influence of our own time-spirit, it would be possible to organise research and develop it without interfering with its essential freedom and initiative, and this in each of the three classes I have mentioned, either by means of some of our existing institutions, or by the inauguration here of such an organisation as the Kaiser Wilhelm Institut in Berlin.

SECTION C.

GEOLOGY.

Opening Address by B. N. Peach, LL.D., F.R.S., President of the Section.

The Relation between the Cambrian Faunas of Scotland and North America.

Introduction.

Ever since the announcement made by Salter in 1859 that the biological affinities of the fossils found in the Durness Limestone are more closely linked with American than with European forms, the relation between the older palæozoic faunas of Scotland and North America has been a subject of special interest to geologists. The subsequent discovery of the *Olenellus* fauna in the north-west Highlands furnished striking confirmation of Salter's opinion. This intimate relationship raises questions of prime importance bearing upon the sequence and distribution of life in Cambrian time in North America and north-west Europe, on the probable migration of forms from one life-province to another, and on the palæogeographical conditions which doubtless affected these migrations.

On this occasion, when the British Association revisits the border of the Scottish Highlands, it seems appropriate to refer to some of these problems. With this object in view I shall try to recapitulate briefly the leading features of the life-history of Cambrian time in Scotland and North America, to indicate the relation which these life-provinces bear to each other, and, from these data, to draw some inferences regarding the probable distribution of land and sea which then obtained in those regions.

The two great rock groups in Scotland that are universally admitted to be older than Cambrian time are the Lewisian Gneiss and the Torridon Sandstone. The Lewisian Gneiss, as mapped by the Geological

Survey, consists mainly of igneous rocks, or of gneisses and schists of igneous origin. But, in addition to these materials, we find, in the Loch Maree region, schists o sedimentary origin, comprising siliceous schist, mica-schist, graphite-schist, limestone, chert, and other sediments. The association of graphite-schist with limestone and chert suggests that we are here dealing with rocks that were formed at or near the extreme limit of sedimentation, where the graphite, the limestone, and the chert were probably accumulated from the remains of plankton. But this assemblage has been so completely altered into crystalline schists that all traces of original organic structure in them have been destroyed.

The Torridonian strata were evidently accumulated under desert or continental conditions, and could therefore furnish little or no evidence bearing upon the development of marine life. That life existed, however, is clear from the presence of phosphatic nodules, containing remains of cells and fibres of organic origin, in the upper division of the system, and from the presence of worm burrows and casts in the Diabaig beds (Lower Torridon).

Geologists are familiar with the fact that the Cambrian faunas all over the globe present highly specialised types belonging to most of the great groups of marine invertebrate life. Scotland is no exception to this general rule. For the fossils prove that their ancestors must have had a long history in pre-Cambrian time.

The Cambrian Fauna of Scotland.

Beginning with the false-bedded quartzites forming the basal sub-division of the Cambrian strata in the north-west Highlands, we find no traces of organic remains in them, except at one locality, where worm casts (*Scolithus linearis*) were obtained. In the upper subdivision of the quartzites—the pipe-rocks—the cylinders of sand are so numerous that the beds have been arranged in five subzones, based on a definite order of succession of different forms probably of specific value. One of them, *Arenicolites* of Salter, may be of generic importance. Worms of this habit are confined to comparatively shallow water, and therefore near the shore line. Their occurrence helps to confirm the belief that the quartzites were laid down on an ancient shelving shore line during a period of gentle subsidence. Their presence also indicates the existence of plankton, from which they derived nourishment. Besides the relics of these burrowing annelids, one of the subzones of the pipe-rock has yielded specimens of *Salterella* (*Serpulites Maccullochii*)—a tubicolar annelid, which becomes more abundant in the overlying fucoid beds, serpulite grit, and basal limestone, where it is associated with *Olenellus* and other typical Lower Cambrian forms.

The fucoid beds, which immediately overlie the pipe-rocks, consist chiefly of shales and brown dolomitic bands, with intercalations of grit locally developed. This type of sedimentation indicates that the mud line was superimposed on the shore line by subsidence. With this change of conditions there is a change of organisms, for though the burrowing forms (*Scolithus*) are still to be found in the sandy layers, the most characteristic types are those occurring along the bedding planes, known under the name of *Planolites* (Nicholson). They are very varied forms, and were probably produced by many types of errant annelids. The tubicolar annelids are represented by *Salterella, Coleoloides,* and *Hyolithes*—an organism which perhaps links the worms with the hingeless brachiopods. This suggestion gains additional support from the researches of Dr. Walcott in the Middle Cambrian rocks of Canada. It is interesting to note that small annelids seem to have bored the spines of dead trilobites. Walcott has found similar borings in the chetæ of annelids in the Middle Cambrian rocks of Canada.[1]

The researches of Dr. Walcott have proved beyond doubt that representatives of nearly all the divisions of the annelids are entombed in the Middle Cambrian rocks of Mount Stephen, in British Columbia. We may therefore reasonably infer that the worm casts of *Scolithus* type found in the north-west Highlands are due to annelids. He has also shown that worm-like holothurians are to be found in the same beds.[2] In this connection it may be observed that some of the recent holothurians have much the same habit of obtaining nourishment from the sands and silts containing organic matter.

Fragments showing the characteristic microscopic structures of the plates and ossicles of echinoderms have been found in the fucoid beds. These are possibly Cystidean. Hingeless forms of brachiopods also occur, among which may be mentioned *Paterina labradorica* and *Acrothele subsidua.* The type of *Acrothele* suggests a genetic descent from such a tubicolar worm as *Hyolithes.* Of the gasteropods, only one specimen, belonging to a subgenus of *Murchisonia,* has been obtained at one locality in Skye. *Helenia bella,* a curved calcareous tube, open at both ends, doubtfully referred to the *Dentalidae* by Walcott, is comparatively plentiful. It occurs also in the *Olenellus* zone in Newfoundland.

But the organic remains that render the fucoid beds of exceptional interest and importance are the trilobites, because they clearly define the horizon of this zone in the Cambrian system and display strong affinities with American types. They are represented by five species and varieties of *Olenellus,* very closely resembling the forms in the Georgian terrane, or *Olenellus* zone, on the east and west sides of the North American continent. The genus *Olenelloides* has also been recorded from these beds. The crustacea are represented by phyllocarids, among which we find *Aristozoe rotundata,* likewise characteristic of the *Olenellus* zone of North America.

Next in order comes the serpulite grit, which indicates a recrudescence of the pipe-rock conditions of deposition, and presents the *Scolithus* type of annelid borings. From the diameter of the pipe and the depth of the burrow it is probable that the worm may have belonged to a different species from any of those the casts of which are to be found in lower horizons. This large variety is associated with smaller and more irregular worm casts which have often weathered out and leave the rock honeycombed with hollow casts. The characteristic form from which the zone takes its name is *Salterella* (*Serpulites Maccullochii*). It occurs abundantly along certain calcareous layers that mark pauses in the deposition of the sand. This calcareous type culminates at the top of the zone, where there is a thick, carious, weathering band, crowded with specimens of *Salterella,* forming a passage bed into the calcareous shales at the base of the Durness dolomites. At one locality near Loch an Nid, Dundonnell Forest, Ross-shire, thin shales, intercalated in the serpulite grit, yielded a fine carapace of *Olenellus Lapworthi*—a form of frequent occurrence in the underlying fucoid beds. Prof. Lapworth recorded the finding of *Orthoceras* and linguloid shells in the top part of this zone at Eireboll.[3]

Immediately above the serpulite grit in Eireboll and Assynt we find a few feet of dark calcareous shale, with iron pyrites, probably deposited at the limit of sedimentation. This layer, which is singularly devoid of organisms, ushers in the great succession of dolomites and limestones, upwards of 1500 feet in thickness—perhaps the most remarkable type of sedimentation among the Cambrian rocks of the north-west Highlands. The Geological Survey has divided this calcareous sequence into seven well-marked groups, some of which have as yet yielded no fossils beyond worm casts. Attention will presently be directed to the absence of calcareous forms in many of the bands of dolomite and to the probable cause of their disappearance.

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[1] Smithsonian Miscell. Collect., vol. lvii., No. 5, p. 125, 1911.

[2] *Ibid.*, No. 3, 1911.

[3] *Geol. Mag.*, vol. x., new series, p. 126, 1883.

The thin calcareous shale just referred to is followed by dark blue dolomite limestone, forming the basal portion of the Ghrudhaidh group. It contains sparsely scattered, well-rounded sand grains, with a bed about three feet thick, near the bottom, charged with *Salterella pulchella* and *S. rugosa.* In the overlying twenty feet of dolomite the sand grains gradually disappear, and the rock assumes a mottled character, due to innumerable worm casts of the *Planolites* type, Here a second layer, yielding *S. pulchella* and *S. rugosa,* supervenes, both forms occurring in the *Olenellus* zone of North America.

The brief summary of the palæontological evidence which has just been given clearly shows that the strata ranging from the middle of the pipe-rock zone to the upper *Salterella* band of the Durness dolomites represent in whole or in part the *Olenellus* zone of North America. Owing to the absence of fossils we have no means of deciding more definitely the base and top of the Lower Cambrian rocks of the north-west Highlands. All the quartzites lying below the middle of the pipe-rock, notwithstanding the absence of zonal forms, have been included in the Lower Cambrian division. This correlation receives some support from the remarkable discovery of Dr. Walcott, who found primitive trilobites several thousand feet beneath the beds yielding *Olenellus Gilberti,* the form closely allied to the Highland trilobites.

On the other hand, when we pass upwards for a certain distance from the *Salterella* bands the evidence is insufficient to establish the stratigraphical horizon of the beds. For in the overlying strata, comprising the remainder of the Ghrudhaidh group, the whole of the Eilean Dubh group, and the lower part of the Sail Mhor group, and consisting of dolomites, limestones, and cherts, with little or no terrigenous material, the only fossils that can be shown to be due to organisms are worm casts of the nature of *Planolites,* although the limestone and chert may have originated from the débris of the calcareous and siliceous organisms of the plankton. A noticeable feature of the Ghrudhaidh and Eilean Dubh groups is the occurrence in them of bands of brecciated dolomite on several horizons, which do not imply any break in the continuous sequence of deposits. The total thickness of this portion of the Durness dolomites and limestones, yielding no fossils beyond worm casts, amounts to 350 feet.

But in the upper part of the Sail Mhor group siliceous and calcareous organisms of a higher grade make their appearance. Among the former we find the *Rhabdaria* of Billings. The calcareous forms are represented by (1) gasteropods, including a single specimen of a murchisonid, two species of a pleurotomarid (*Euconia Ramsayi* and *E. Etna*) of a type occurring in the calciferous rocks of Newfoundland and Canada; (2) cephalopods, comprising two slightly bent forms with closely set septa and wide endogastric siphuncles, showing affinities with those of *Endoceras* and *Piloceras*; (3) arthropods, represented by the epitome of a large asaphoid trilobite resembling that of *Asaphus canalis* of Conrad. This evidence is insufficient to determine the exact horizon of these beds, but clearly indicates that we are no longer dealing with Lower Cambrian strata. The cephalopods are like those found in the Ozarkic division of Ulrich (Upper Cambrian), in North America. According to Schuchert, the cephalopods with closely set septa are of Cambrian type and older than those of the Beekmantown terrane of American geologists. On the other hand, the asaphoid type of trilobite is suggestive of a somewhat higher horizon.

No fossils have been found in the overlying Sangomore group, about 200 feet thick, which consists mainly of granular dolomite, with bands of chert, some being oolitic, together with thin fine-grained limestones near the top.

Above this horizon, at a height of more than 800 feet above the top of the *Olenellus zone,* we encounter the great home of the fossils peculiar to the Durness limestone in the Balnakeil and Croisaphuill groups. The former consists mostly of dark limestones, with nodules of chert, and, with a few alternations, of white limestone bands. A few thin layers are charged with worm casts. The overlying group is more varied, the lower part being composed of dark grey limestones full of worm casts, and with some small chert nodules arranged in lines; the middle portion, of dark granular and unfossiliferous dolomite; and the upper part, of massive sheets of fossiliferous limestone full of worm casts. The total thickness of these two groups in Durness is about 550 feet.

These two subdivisions have yielded more than twenty genera and about one hundred species. In Durness sixty-six species have been obtained from the Balnakeil group alone, fifteen of which have not as yet been found in the overlying Croisaphuill group, thus leaving fifty-one species common to both divisions. The Ben Suardal limestones in Skye, which were mapped by the Geological Survey as one division, are regarded, on palæontological grounds, as the equivalents of both these groups. Owing to the number of species common to both subdivisions, the fauna will be here referred to as a whole.

Both siliceous and calcareous organisms are present in this fauna. Among the former we find *Archaeoscyphia* (Hinde), described by Billings as *Archaeocyathus,* an early Cambrian coral, but shown by Hinde to be a siliceous sponge.[4] The genus *Calathium* is represented by four species. Other genera and species of sponges occur, so that the siliceous nodules, which are very common in both groups, may be in great part due to them In this connection it may be mentioned that Hinde obtained sponge spicules from some of the nodules. Hinged brachiopods have also been collected from these beds, and include *Nisusia* (*Orthosina*) *festinata, N. grandaeva,* and Camarella.

But the characteristic feature of the fauna is the assemblage of calcareous mollusca comprising lamellibranchs, gasteropods, and cephalopods, showing a wide range of variation, and consequently a long ancestry. The lamellibranchs, though represented only by two genera, *Euchasma* and *Eopteria* of Billings, with several intermediate forms, are of extreme interest, as they are only known to occur elsewhere in Newfoundland and eastern Canada. The gasteropods, however, furnish the largest number of species —about 48 per cent. of the whole. The primitive euomphalids, *Maclurea* and *Ophileta,* are most characteristic. The former genus has a large number of species, many of which are to be found in the Beekmantown limestone of Newfoundland and eastern North America. Only one of the species (*Maclurea Peachi*) is peculiar to Durness. Several species of

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[4] Quart. Jour. Geol. Soc., vol. xlv., p. 125, 1889

Ophileta are found, some of which likewise occur in the Beekmantown limestone. Euomphalus has also been recorded, while several forms belonging to the nearly allied family of the Turbinidæ, and placed in Lingström's genus *Oriostoma*, are also met with in the Beekmantown limestone.

Murchisonids and Pleurotomarids number twenty-seven species and show a very wide range of variation. The chief subgenera of the former are *Hormotoma* and *Ectomaria*, many species of which occur with remarkable variations. All the types of variation found in Durness are to be found in North America, and several of the species are common to both regions. The pleurotomarids vary in a similar manner, the chief genera being *Raphistoma* and *Euconia*, and a form resembling *Hormotoma*, only with a shorter spire. Species belonging to each of these subgenera are likewise common to both areas, while some are only known from the north-west Highlands.

The cephalopods are of equal interest. They are also of primitive type, and, at the same time, show a wide range in form. The prominent feature in the straighter specimens is the great width of the laterally placed siphuncle, which is generally furnished with endocones and organic deposits. The genus *Piloceras* is the most characteristic type and shows this peculiar feature best. It has only been recorded from Scotland, Newfoundland, Canada, and the eastern States of North America. The following additional genera are represented, viz. *Endoceras*, chiefly by siphuncles in great variety; *Actinoceras, Cyrtoceras*, and, doubtfully, *Orthoceras*. Several forms have been attributed to *Orthoceras* which, on re-examination have been found to be the siphuncles of other genera, resembling American types described by Hall and Whitfield.

The whorled nautiloids provisionally classed with the genus *Trocholites* of Conrad are represented by several distinct forms as yet unnamed.

The trilobites are of rare occurrence in these two groups of dolomite and limestone. They are fragmentary and poorly preserved. This is doubtless one of the disappointing features connected with this remarkable assemblage of organic remains, for the presence of a zonal form would have helped to define the horizon of these beds. Only one species, *Bathyrus Nero* (Billings) has been identified, which also occurs in the Beekmantown limestone of Newfoundland. The other trilobite remains, though poorly preserved, leave a Cambrian facies characteristic of North America.

In connection with this fauna certain features have been observed which throw some light on the absence of calcareous organisms from thick zones of the Durness dolomite and limestone. In my detailed description of the palæontology of the Cambrian rocks of the north-west Highlands in the Geological Survey Memoir I stated that "in most cases the septa and walls of chambered shells have been wholly or in part dissolved away, so as to leave only the more massive structures of the siphuncles, and worm castings are often found within the chambers where the septa have been preserved. These features seem to indicate that the accumulation of the calcareous mud in which the fossils were embedded was so slow that there was time for the solution of part of an organism before the whole of it was covered up."[5] There is good reason to believe that many organisms wholly disappeared by this process, so that it is reasonable to conclude that the fossils obtained from the Durness dolomites cannot be regarded as furnishing a complete life-history of the forms that originally existed in that sequence of deposits. Attention has already been directed to the fact that beneath the two subdivisions now under consideration there are groups of dolomite and limestone which so far have yielded no organic remains beyond worm castings. And even in the important Croisaphuill group, with its fossiliferous zones, there are thick groups of dolomite which have furnished no calcareous organic remains. Obviously the palæontological record in this instance is glaringly incomplete, for we have no reason to suppose that the life of the time flourished in some of the calcareous zones and not in others.

The highest subdivision of the Durness limestone, measuring about 150 feet in thickness (Durine group), has yielded two species of *Hormotoma*—viz. *H. gracilis* and *H. gracillima*—both of which occur in the two underlying groups. *H. gracilis* occurs in the Beekmantown, the Chazy, and the Trenton limestones of America.

Before assigning any stratigraphical horizons to the fauna of the Durness dolomites, it is desirable, owing to the American facies of the fossils, to recapitulate the evidence bearing upon the life of Cambrian time in North America. But the Cambrian life-history of Scotland would be incomplete without a brief reference to the recent discovery of fossils along the eastern border of the Highlands.

In 1911 Dr. Campbell announced in *The Geological Magazine* that fossils had been found in the Highland border series north of Stonehaven, and, during this year, Dr. Jehu made a similar discovery in rocks belonging to this series near Aberfoyle. Papers on these subjects will be communicated to this section. For my present purpose it will be sufficient to indicate the nature of the fossils and the lithological characters of the rocks containing them.

The Highland border series north of Stonehaven and near Aberfoyle includes sheared igneous rocks, both lavaform and intrusive, with black shales, cherts, and jaspers. North of Stonehaven the fossils occur in thin, dark, flinty pyritous shale, while at Aberfoyle they have been found in shaly films at the edge of the chert bands. Several years ago radiolaria were detected in the cherts between Aberfoyle and Loch Lomond. From time to time these Highland border rocks have been carefully searched for fossils, but until recently with little success, owing to the intense movement to which they have been subjected, resulting in marked flaser structure in all except the most resistant bands.

The fossils consist chiefly of horny, hingeless brachiopods, phyllocarid crustacea, worm-tubes, and the jaws and chetæ of annelids. The genera of brachiopods comprise *Lingulella, Obolus, Obolella, Acrotreta*, and *Linarssonia*. The association of these brachiopods with phyllocarid crustaceans resembling *Hymenocaris* and *Lingulocaris* is suggestive of an Upper Cambrian horizon—an inference which is supported by the absence of graptolites.

In the published Geological Survey maps these Highland border rocks are queried as of Lower Silurian age. This correlation was based partly on their resemblance to the Arenig volcanic rocks and radiolarian cherts of the southern Uplands, and partly because, as shown by Mr. Barrow, they are overlain by an unconformable group of sediments, termed by him the Margie series. The cherts, the green schists, and the Margie series have shared in a common system of folding, and are unconformably surmounted by Downtonian strata near Stonehaven. Though the original correlation may not be strictly correct, it is probable, in my opinion, that representatives of both the Arenig and Upper Cambrian formations may occur in the Highland border series, and, further, that Upper Cambrian strata may yet be found in the Girvan area, as originally suggested by Professor Lapworth in correspondence with Dr. Horne.

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[5] "Geological Structure of the North-west Highlands," Geol. Sur. Mem., 1907, p. 380.

The Cambrian Fauna of North America.

The classification of the Cambrian fauna found in North America is based on the researches of a band of distinguished palæontologists, comprising among the older investigators Billings, Hall, and Whitfield, and among modern workers Walcott, Ulrich, Schuchert, Brainerd, Seely, Ruedemann, Matthew, Clarke, and Grabau. Prominent among these investigators stands Dr. Walcott, alike for his original and exhaustive contributions to this branch of inquiry and for his complete mastery of the sequence and distribution of life in Cambrian time in North America. Indeed, geologists all over the world owe him a deep debt of gratitude for the services which he has rendered to Cambrian palæontology.

Throughout the greater part of Cambrian time there existed in North America two distinct life provinces. The eastern one ran along the Atlantic coast from the north of Newfoundland to a point south of New York, extending only a short distance inland, with a faunal facies resembling that of north-west Europe, exclusive of the north-west Highlands of Scotland. The western province lay to the north-west of that just described, and ranged from northern Newfoundland, south-westwards to Central North America and the Pacific Ocean. On the east side of the Rocky Mountains it swept northwards to British Columbia, perhaps as far as the Arctic Ocean. The remarkable feature of the life of the western province is its essentially American facies.

Geologists are familiar with the triple classification of the Cambrian system by means of the trilobites in North America, as in Europe. The Lower Cambrian division represents the *Olenellus* epoch of Walcott, characterised by some form of Olenellid, or, to use the name now given to the family by that investigator, the *Mesonacidae*. The western life-province contains the true *Olenellus* of which *O. Thompsoni* is the type. The strata yielding this fauna extend over such a wide area of North America that within this same province we find a western and an eastern facies. The western facies is found in Nevada and California, where *Olenellus* is represented by such specific forms as *O. Gilberti* and *O. Freemonti*. But it is noteworthy that these forms occur near the top of the Lower Cambrian series, and are soon followed by *Zacanthoides* and *Crepicephalus*, trilobites of Middle Cambrian affinities. Towards the lower part of the sequence of deposits, which there consist mainly of limestone, and extend downwards for a distance of more than 4000 feet beneath the beds containing the true *Olenellus*, Walcott found specimens of *Holmia Rowei* and *Nevadia Weeksi*. The latter form is regarded by him as the most primitive of all the *Mesonacidae* yet known. Near the base the limestones have yielded the primitive corals, *Archaeocyathus* and *Ethmophyllum*; and the brachiopods *Mickwitzia* and *Trematobolus*. The other forms found on this horizon belong to the following genera: (trilobites) *Protypus* and *Microdiscus* (brachiopods) *Kutorgina, Swantonia, Nisusia, Billingsella,* and (tubicolar annelids) *Hyolithellus* and *Salterella*. The eastern facies of the western life-province is best known from the region of Georgia, in Vermont. It is the home of the type species of *Olenellus* (*O. Thompsoni*). It is associated with *Mesonacis vermontana*, which has now given the name to the whole family, with *Elliptocephalus asaphoides*, one of the earliest known trilobites of the family, and with other forms such as *Bathynotus, Holopygia, Protypus*, and *Microdiscus*. The tubicolar worms are represented by *Hyolithellus* and *Salterella*, the brachiopods by *Nisusia, Swantonia, Kutorgina cingulata*, and *Paterina labradorica*. There can be no doubt that the assemblage of organic remains found in this Georgian terrane is merely the counterpart of that found in the *Olenellus* zone of the north-west Highlands.

Proceeding now to the eastern life-province, we find that the Lower Cambrian rocks are characterised by the trilobite genus *Callavia*, belonging to the family of the *Mesonacidæ*, and bearing a close resemblance both to *Holmia* and *Nevadia*. In southern Newfoundland two species of *Callavia* occur, of which *C. Bröggeri* is the type. It is accompanied by *Microdiscus, Hyolithellus, Paterina labradorica*, and *Helenia bella*. In New Brunswick the *Protolenus* fauna, with *Protolenus* as the characteristic trilobite, probably represents the upper part of the *Olenellus* zone. In this connection the recent discovery of the *Protolenus* fauna by Mr. Cobbold, in Shropshire, in strata associated with *Callavia*, and overlain by beds yielding *Paradoxides*, is of special importance, as it shows the close relation between the Lower Cambrian fauna of Wales and that of the Atlantic or eastern province of North America.[6]

The Middle Cambrian division of the western life-province is characterised chiefly by the trilobite genus *Olenoides*; indeed, the western part of it is the home of *Olenoides* and the large-tailed trilobites. The characteristic genera of this group to be found in that region are *Kootenia, Zacanthoides, Bathyuriscus, Asaphiscus, Neolenus, Dorypygella, Dorypyge, Damesella*, and *Ogygopsis*.

In this region the Middle Cambrian limestones and shales occurring on Mount Stephen, in British Columbia, have yielded a magnificent series of trilobites, eurypterids, limuloids, crustacea ranging from congeners of the brine shrimps to phyllocarid nebalids, annelids belonging to most of the still extant families, holothurians, medusae, and other organic remains. For the most part many of these forms are so fragile that only their tracks remain as indications of their existence in palæozoic deposits. Not till we reach the Solenhofen slates in Jurassic time do we find similar favourable conditions for the entombment and preservation of their highly modified successors. The remarkable evidence bearing on the evolution of groups of organisms furnished by this assemblage of fossils from Mount Stephen has been admirably described and illustrated by Walcott in his series of papers published in the Smithsonian Miscellaneous Collections.

In the New Brunswick portion of the eastern or Atlantic life-province the strata yielding *Paradoxides* follow those bearing the *Protolenus* fauna. Six species of Paradoxides have been obtained from this horizon, including *P. davidis*, together with the following genera: *Agnostus, Agranlos, Liostracus, Conocoryphe*, and *Ctenicephalus*. Schuchert points out that this fauna is "closely allied to the *Paradoxides* faunas of Wales and Sweden, but less so with that of Bohemia."[7]

In southern Newfoundland Walcott showed that the base of the Middle Cambrian division is marked in Manuel's Brook by a conglomerate containing fossils of the lower or Georgian terrane, thus indicating elevation and erosion of the Lower Cambrian rocks. Higher up the strata yielded *Paradoxides davidis* and *P. bennetti*.

Important evidence pointing to the conclusion that the *Paradoxides* fauna of the eastern or Atlantic province encroached to some extent on the eastern part of the western life-province has been obtained by Walcott at St. Albans, Vermont. But the suggestion has been made by Schuchert that their present position is there due to north-westerly thrusting.[8]

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[6] Quart. Jour. Geol. Soc., vol. lxvii., p. 296, 1911.

[7] Bull. Geol. Soc. of Amer., vol. xx. (1910), p. 522.

[8] *Ibid.*

It should be borne in mind that in Middle Cambrian time the eastern and western parts of the western life-province were evidently separated from each other by a land barrier, owing to crustal movement, which was probably connected with the elevation of the Lower Cambrian rocks in the region where they were subjected to erosion.

In the upper division of the Cambrian system in North America there is a marked change in the fauna. Its characteristic features are thus clearly summarised by Schuchert: "In a general way it may be said that the Ozarkic period of Ulrich (Upper Cambrian) begins with the trilobite genus *Dikelocephalus* and the first distinct molluscan fauna. . . . The trilobites and inarticulate brachiopods (greatly reduced in species) are still Cambrian in aspect, while the new faunal feature consists in a rapid evolution, in form and size, of the coiled gasteropods, and of both straight and coiled cephalopods. The latter are distinguished from those of subsequent periods by the exceedingly close arrangement of the septa."[9]

The distinctive trilobite genus of the Upper Cambrian strata of the western life-province is *Dikelocephalus,* where it is associated with an American facies of fossils. The eastern or Atlantic province is characterised by Olenids, though *Dikelocephalus* also occurs, and by typical European forms. In Minnesota and Wisconsin, where the strata consist of sandstones, dolomites, and shales, two species of *Dikelocephalus* have been obtained, together with other genera of trilobites such as *Agnostus* and *Illaenurus;* the limuloid *Aglaspis*; and the gasteropods *Holopea, Ophileta,* and *Raphistoma.*

In certain areas this period is characterised by a great succession of calcareous deposits, comprising parts of the Shenandoah limestone and Kittatinny dolomite in New Jersey, portions of the Knox dolomite in Tennessee, and of the dolomite and limestone in Oklahoma. In some of these localities, at least, the lower portions of this calcareous series are grouped with the Upper Cambrian sediments, while the upper parts are classed with Lower Silurian or Ordovician strata. The researches of American palæontologists have shown that in certain areas there is a mixed Cambrian and Ordovician fauna in some of the beds, as in the Tremadoc rocks of Wales. This commingling of faunas is exemplified in the case of the Beekmantown limestone, which is grouped with the Ordovician (Lower Silurian) rocks by most American geologists. Ulrich and Schuchert, on the other hand, regard it as a formation (the Canadic) distinct from the overlying Ordovician system.

The type areas of the Beekmantown limestone are Lake Champlain, the Mingan Islands, and Newfoundland, where the strata consist mainly of a succession of limestones and dolomites more than 1000 feet thick. The fossils are chiefly molluscan, comprising lamellibranchs, gasteropods, and cephalopods. The lamellibranchs are represented, among others, by the genera *Euchasma* and *Eopteria*; the gasteropods by *Ophileta, Maclurea, Euomphalus, Holopea, Hormotoma, Ectomaria, Murchisonia, Lophospira, Euconia, Raphistoma, Helicotoma*; the cephalopods by *Orthoceras, Cyrtoceras, Gomphoceras, Piloceras, Trocholites.* Of the foregoing genera many of the species are common to this region and the north-west Highlands of Scotland.

The trilobites associated with this fauna comprise the genera *Dikelocephalus, Bathyrus, Asaphus, Harpes,* and *Nileus.*

In northern Newfoundland, in zones F to N of Billings, this fauna, with localised species, is found in great development in limestones and dolomites resembling those of Durness. Its upper limit is there clearly defined, for the limestones and dolomites are overlain by dark shales containing graptolites of undoubted Arenig age.

A careful comparison of the faunas of the Durness and Beekmantown limestones shows that the assemblage of fossils in the Balnakeil and Croisaphuill groups of Durness is practically identical with that in the zones F to N of Billings, as developed in Newfoundland. These groups must therefore be older than the Arenig rocks of Wales, and must represent at least the Welsh Tremadoc strata, if not part of the Lingula Flags, both of which, according to the English classification, are grouped with the Cambrian system.

But even in the purely European province of North America, in New Brunswick, where the Beekmantown calcareous fauna is entirely absent, and where the faunal sequence and type of sedimentation are almost identical with those of North Wales, the basal Ordovician or Lower Silurian rocks of American geologists include the *Peltura scarabaeoides* and the *Parabolina spinulosa* zones, which, in Wales, are classed with the Lingula Flags. It is obvious, therefore, that the boundary-line between the Cambrian and Ordovician (Lower Silurian) systems is not drawn at the same stratigraphical horizon by American and British geologists. In fixing the age of the Durness dolomites and limestones the English classification has been adopted.

The palæontological evidence now adduced regarding the relation of the Cambrian fauna of the north-west Highlands to that of North America leads to the following conclusions:—

1. The Lower Cambrian fauna of the north-west Highlands, distinguished by the genus *Olenellus* and its associates, is almost identical in character with that of the Georgian terrane of the western life-province of North America, and essentially different from the Lower Cambrian fauna of the rest of Europe.
2. No forms characteristic of the Middle Cambrian division, either of Europe or North America, have as yet been found in the north-west Highlands; but this division may be represented by the unfossiliferous dolomites and limestones of the Ghrudhaidh, Eilean Dubh, and the lower Sail Mhor groups.
3. The fossiliferous bands of the Sail Mhor group may be the equivalents of the lower part of the Upper Cambrian formation.
4. The Balnakeil and Croisaphuill groups of the Durness dolomites and limestones contain a typical development of the molluscan fauna of the Beekmantown limestone, belonging to the western life-province of North America. As the Beekmantown limestone is succeeded by shales, with Arenig graptolites, it follows, in accordance with British classification, that these groups must be of Upper Cambrian age.
5. The highest subdivision of the Durness limestone (Durine) has not yielded fossils of zonal value, and the members of this group are not overlain in normal sequence by graptolite-bearing shale or other sediments.

Cambrian Palaeogeography between North America and North-West Europe.

In attempting to restore in outline the distribution of land and sea in Cambrian time between North America and north-west Europe reference must be made to various investigators whose researches in palæogeography are more or less familiar to geologists. Among these may be mentioned Suess, Dana, De Lapparent, Frech, Walcott, Ulrich, Schuchert, Bailey Willis, Grabau, Hull, and Jukes Browne. The views now presented seem to me to be reasonable inferences from the palæontological evidence set forth in this address.

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[9] *Op. cit.*, p. 524.

In the north-west Highlands there is still a remnant of the old land surface upon which the Torridonian sediments were laid down. There is conclusive evidence that the pre-Torridonian land was one of high relief. As the Torridonian sediments form part of a continental deposit it may be inferred that the Archæan rocks had a great extension in a northwesterly direction. The increasing coarseness of the deposits towards the north-west suggests that the land may have become more elevated in that direction. At any rate, the pile of Torridonian sediments points to a subsidence of the region towards the south-east, and probably to a correlative movement of elevation towards the north-west.

The sparagmite of Scandinavia is an arkose resembling the dominant type of the Torridon sandstone; is of the same general age, and has evidently been derived from similar sources in the Scandinavian shield. In eastern North America coarse sedimentary deposits form part of the newer Algonkian rocks, which are still to be found rising from underneath the Cambrian strata in the region of the great lakes. These materials were obtained from the great Canadian shield, which must have formed a large continental area during their deposition.

It is reasonable to infer that these isolated relics of old land surfaces were united in pre-Torridonian time, thus forming a continuous belt from Scandinavia to North America. During the period which elapsed between the deposition of the Torridon sandstone and the basement members of the Cambrian system a geosyncline was established which gave rise to a submarine trough, trending in an east-north-east and west-south-west direction, both in the British and North American areas. In the latter region it extends from Newfoundland to Alabama, its south-eastern limit being defined by the old land surface of Appalachia. The extension of this Appalachian land area in a north-east direction beyond the limits of Nova Scotia and Newfoundland was postulated by Dana and other American writers. This geosyncline remained a line of weakness throughout palæozoic time, both in Britain and North America, which resulted in the Caledonian system of folding in Britain, and in the Taconic, Appalachian, and Pennsylvanian systems in North America. Hence it is manifest that the original shore-lines of this trough are now much nearer each other than they were in Cambrian time.

The Cambrian rocks of the north-west Highlands were laid down along the north-west side of this trough during a period of subsidence, for the great succession of Durness dolomite and limestone, with little or no terrigenous material, is superimposed on the coarser sediments of that formation. On the other hand, the Cambrian strata of Wales seem to have been deposited along the southern limit of this marine depression. The Archæan rocks that now constitute the central plateau of France may have formed part of its southern boundary. The extension of this land area towards the north-east may have given rise to the barrier that separated the Baltic life-province from that of Bohemia, Sardinia, and Spain. In my opinion this southern land area in Western Europe was continuous across the Atlantic with Appalachia. For the life sequence found in the Cambrian rocks of New Brunswick is practically identical with that of Wales and the Baltic provinces, thus showing that there must have been continuous intercourse between these areas. Along this shoreline the migration of forms seems to have been from Europe towards America. On the other hand, along the northern shore the tide of migration seems to have advanced from America towards the north-west Highlands. The question naturally arises, what cause prevented the migration of the forms from one shore of this trough to the other? American geologists are of opinion that this is probably due to the existence of land barriers; but, in my opinion, it can be more satisfactorily accounted for by clear and open sea, aided by currents.

The south-western extremity of the American trough in Lower Cambrian time opened out into the Mississippian sea, which was connected with the Pacific Ocean, and stretched northwards towards the Arctic regions. Reference has already been made to Walcott's discovery in Nevada of the primitive trilobite *Nevadia Weeksi*, from which he derives both branches of the *Mesonacidae*, one branch linking *Nevadia*, through *Callavia*, *Holmia*, and *Wanneria*, with *Paradoxides*, the other connecting *Nevadia* with *Olenellus*, through *Mesonacis*, *Elliptocephalus* and *Paedumias*.

In Nevada the genus *Holmia*, as already shown, is associated with the primitive type *Nevadia*. *Wanneria* is found in Nevada, in Alabama, and in Pennsylvania, thus showing that this genus is common to the Missisippian sea and to the long trough north-east of Alabama. *Mesonacis* has been obtained in the submarine depression at Lake Champlain, at Bonne Bay, Newfoundand, and at the north side of the Straits of Belle Isle. *Elliptocephalus* has been recorded from the New York State. *Olenellus* has been found in Nevada, in Vermont, and in the north-west Highlands. All the genera now referred to may have migrated along the north-western shore of this trough.

As regards the distribution of the genus *Callavia*, this form has been met with in Maine, in Newfoundland, and in derived pebbles in a conglomerate in Quebec. Two species have been recorded in Shropshire. These forms probably moved along the southern shore of this sea from Wales to North America.

Reference has already been made to the fact that, in the interval between Lower and Middle Cambrian time, in certain areas in North America the Lower Cambrian rocks were locally elevated and subjected to erosion. During this interval the southern end of the trough seems to have had no connection with the Mississippian sea, for in Middle Cambrian time, as already indicated, the *Paradoxides* fauna is found in the trough on the east side of North America, whereas on the west side it is represented by the *Olenoides* fauna.

In Upper Cambrian time a great transgression of the sea towards the north supervened. The *Dikelocephalus* fauna is found on both sides of America, thus showing that the previous land barrier had been submerged. While this genus occurs in Wales and the Baltic provinces, it has not as yet been recorded from the north-west Highlands, but I quite expect that this discovery may be made at some future time.

Along the northern side of the American trough clear water conditions prevailed, owing to the northward recession of the shore-line, which led to the accumulation of a great succession of calcareous deposits, including the Beekmantown limestone, to which reference has already been made. Schuchert, as already stated, has pointed out that, in the lower part of the Ozarkic (Upper Cambrian) system, in Minnesota and Wisconsin, the gasteropod genera *Hoopea*, *Ophileta*, and *Raphistoma* are associated with two species of *Dikelocephalus*. This molluscan fauna is evidently the precursor of that of the Beekmantown limestone. It was probably from this central region of America that the calcareous fauna of Beekmantown migrated to the submarine trough in the typical Champlain region, and through Newfoundland to the north-west Highlands of Scotland.

The section at St. John, New Brunswick, where the Baltic and Welsh types of the *Olenus* fauna occurs, shows that the southern shore line of the trough must then have occupied much the same relative position as in Lower and Middle Cambrian time. In the same region the strata containing this fauna, with *Peltura scarabaeoides* and *Dictyonema flabelliforme,* are overlain by dark shales with Arenig graptolites. These graptolite-bearing terrigenous deposits eventually extended across the trough northwards, until, in Newfoundland, they came to rest on the Beekmantown limestones.

In the Lake Champlain region, in the Chazy limestone, which there immediately succeeds the Beekmantown limestone without the intervention of the Arenig graptolite shale, there is a survival of the Beekmantown molluscan fauna with only such slight modifications as to indicate genetic descent. In the same trough the descendants of this fauna are to be found in the Trenton limestone.

In this connection it is worthy of note that the molluscan fauna and the corals of the Stinchar and Craighead limestones of Upper Llandeilo age in the Girvan district of the Southern Uplands have an American facies, as first suggested by Nicholson. The appearance of American types in these limestones may be accounted for in the following manner: attention has already been directed to the divergent types of sedimentation presented by the Upper Cambrian strata of the north-west Highlands, and of the south-east Highlands, at Stonehaven and Aberfoyle. In the former case there is a continuous sequence of dolomites and limestones, while in the latter we find a group, comprising radiolarian cherts and black shales, associated with pillowy spilitic lavas and intrusive igneous rocks, indicating conditions of deposition at or near the limit of sedimentation. But, notwithstanding the different types of sedimentation and the divergent faunas in the two areas, I believe that during the Upper Cambrian period, and probably for some time thereafter, continuous sea extended from the north-west Highlands to beyond the eastern Highland border. The Upper Cambrian terrigenous sediments which we now find at Stonehaven and Aberfoyle must have been derived from land to the south. In Llandeilo time the Arenig and Lower Llandeilo rocks of the Girvan area were elevated and subjected to extensive denudation. On this highly eroded platform, as first proved by Prof. Lapworth, coarse conglomerates, composed of the underlying materials, were laid down in association with the Stinchar and Craighead limestones. In my opinion the appearance of the American forms in these limestones is connected with the movement that produced this unconformability in the Girvan area. This local elevation was probably associated in some form with the great crustal movements that culminated in the overthrust of the north-west Highlands and caused the intense folding and flaser structure of the rocks along the Highland border. By these movements shore-lines may have been established between the north side of the old Palæozoic sea and the Girvan area, which permitted the southern migration of the American forms.

Note.—Since writing the above my attention has been directed to the recent work of Bassler on "The Early Palæozoic Bryozoa of the Baltic Provinces," published by the Smithsonian Institution in 1911. In his introduction the author has shown that the Ordovician (Lower Silurian) and Gothlandian (Upper Silurian) rocks of the Baltic provinces contain a larger percentage of bryozoan species, in common with the Black River, Trenton, and Niagara limestones of the same relative age in eastern North America. This fact suggests that during Lower and Upper Silurian time the old lines of migration were still open, and that the Bryozoa, being of clear-water habit, were able to cross the old trough from side to side.

NOTES.

FROM a Press cutting just received from Sydney we learn that Mr. Fisher, Prime Minister, Australia, referred to the forthcoming visit of the British Association in 1914 in his Budget speech on August 1. He said:—"We have been advised that about half as many more members of that association are likely to visit the Commonwealth than was anticipated when our invitation was accepted. This will entail an increase in the amount of money which I propose to give towards their expenses; and, speaking for this Parliament and country, I say that no greater compliment could be paid to Australia than the fact that our visitors are to be increased in number. It is usual a year or eighteen months before the visit is made to send a representative man of the same class as themselves to get into communication with them. We propose to incur that expenditure pending the expenditure of a larger amount to cover their expenses."

THE Chancellor of the Royal Prussian Ordre pour le Mérite has, through the German Embassy, informed Sir William Turner, K.C.B., F.R.S. vice-chancellor and principal of the University of Edinburgh, that the German Emperor has appointed him to be knight of the Order in the department of science. The number of those on whom this Order is conferred is strictly limited, and since 1885, when Lord Lister was appointed, Sir John Murray, Sir Joseph D. Hooker, Lord Avebury, Lord Rayleigh, the Right Hon. James Bryce, Sir David Gill, and Sir Wm. Ramsay have been its recipients. The death of Lord Lister having caused a vacancy, his Majesty the Emperor has been pleased to confer the Order on Sir Wm. Turner, in recognition of the contributions which he has made to anatomical science.

THE fourteenth meeting of the Australasian Association for the Advancement of Science will be held in Melbourne in January, 1913.

THE Royal Aero Club has decided to award its gold medal to Mr. S. F. Cody in recognition of his victory in the recent War Office aeroplane trials.

MR. T. H. MOTTRAM has been appointed to succeed the late Mr. Pickering as divisional inspector of mines in charge of the Yorkshire and North Midlands District. Mr. J. R. Wilson, of Leeds, will fill the position vacated by Mr. Mottram.

WE regret to see the announcement of the death, on September 4, of Dr. Stanley Dunkerley, formerly professor of engineering, Manchester University, and the Royal Naval College, Greenwich, and the author of a standard work on "Hydraulics."

THE departmental committee appointed by the Home Office to consider the best methods of testing miners' safety lamps reports that the official tests for flame